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DESIGN AND ANALYSIS OF MINI-UAV

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ABSTRACT

The aim was to design and analyze a mini UAV for a surveillance mission. To achieve the final vehicle, a novel design methodology, based on cruise optimization was incorporated to carry out the design and development of mini UAV with AUW of max 2.5 kg, and the maximum wing span of 1.5 m. The methodology incorporates the design of the low Reynolds number wing, by optimizing the different disciplines aerodynamics, structures, propulsion, etc. The wing designed is optimized for the cruise flight, since the mission is for surveillance. The procedure also illustrates the major decisions made, during the development of the mini-UAV viz. airfoil selection, wing loading, aspect ratio wing plan-form shape etc.

Finally, we want to achieve good aerodynamic efficiency during flight conditions near to 200,000 Reynolds's number and to compare the obtained computational values with experimental values.

KEYWORDS: Unmanned Aerial Vehicle, Aspect Ratio, Maximum Take-off Weight, Medium Altitude Long Range & Micro Electromechanical Systems

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Original Article

INTRODUCTION

The UAV is also called as a drone. UAVs are used to carry and launch like an infantry man portable air-defense system. It is used to Map the landslide affected area and infested crop damage assessment.

UAV Components

UAV components are

- The vehicle or platform;
- Its payload; and
- Its ground-control system

DESIGN SPECIFICATION AND SELECTION OF AERODYNAMIC PARAMETERS

Table 1: Requirements based on the Initial Assumptions

Estimated Value		Calculâtes Value based on the Estimated Value	
Wing Loading	100 N/m^2	$C_{Lcruise}$	0.73
Aspect Ratio	9	Wing Area	0.245 m^2
Taper Ratio	0.5	Wing Span	1.485
Oswald's Efficiency Factor	0.8	Chord (Root, Tip)	0.220,0.110

Table 2: List of Selected Airfoils

Airfoil	Camber	Thickness	Re=200000	
			C_{lmax}	C_l/C_d
DW T-1	7.11 (35.2)	13.45 (26)	1.52	71
E216	5.17 (55.21)	10.44 (27.81)	1.6	100
FX 63-110	4.36 (54.17)	11.04 (28.16)	1.65	92
N-22	6.23 (30.40)	12.39 (28)	1.52	72
S4310	4.16 (39.80)	10.86 (30.40)	1.45	81

Table 3: Airfoil Analysis

Airfoil	L/D @ $C_{lcruise}$	A_{cruise}	C_{lmax}	C_{d0}
DW T-1	22.8	1.5	1.45	0.020
E216	20.8	2.2	1.55	0.028
FX 63-110	23.1	2.3	1.60	0.020
N-22	23.1	2.2	1.45	0.019
S4310	22.8	4.1	1.41	0.025

Airfoil Geometries are shown below

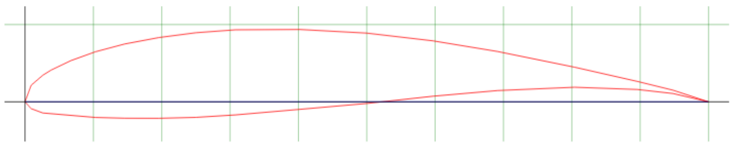

Figure 1: Fx 63-110(Wing Airfoil)

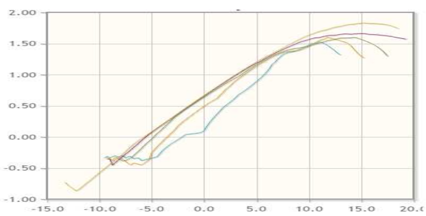

Figure 2: C_L Vs Alpha

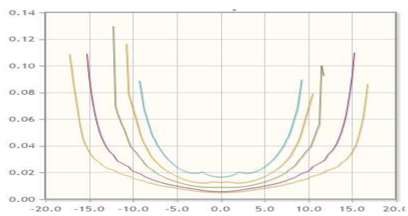

Figure 3: C_D Vs Alpha

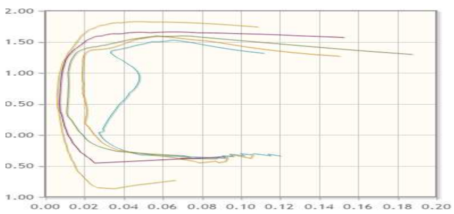

Figure 4: C_L Vs C_D

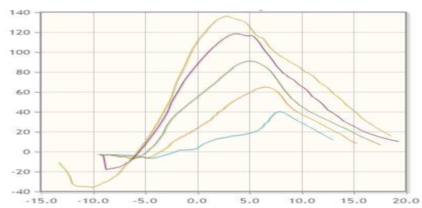

Figure 5: C_L/C_D Vs Alpha

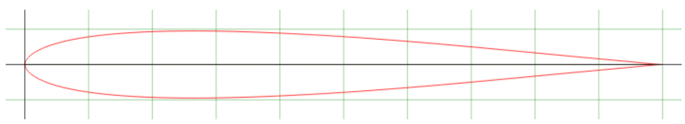

Figure 6: S9026 (Horizontal Tail Airfoil)

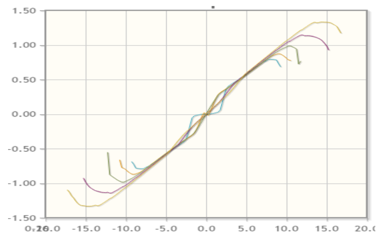

Figure 6: C_L Vs Alpha

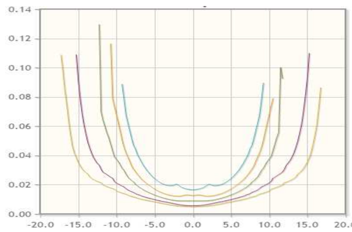

Figure 7: C_D Vs Alpha

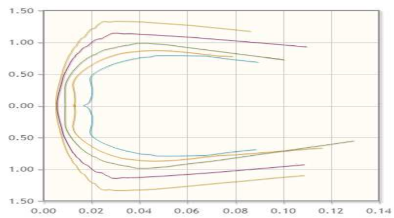

Figure 8: C_L Vs C_D

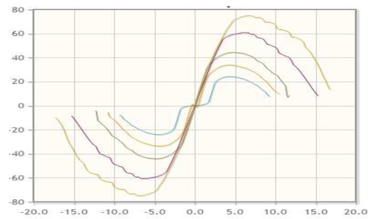

Figure 9: C_L/C_D Vs Alpha

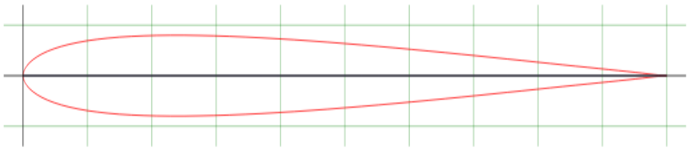

Figure 10: S9027 (Vertical Tail Airfoil)

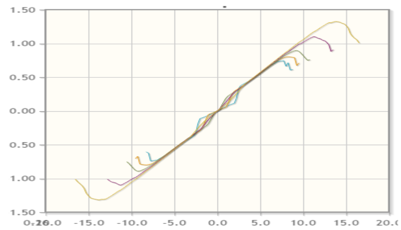

Figure 11: C_L Vs Alpha

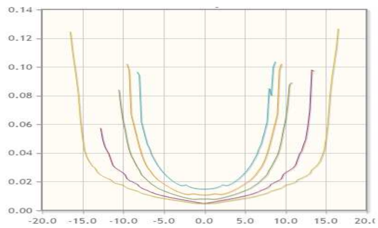

Figure 12: C_D Vs Alpha

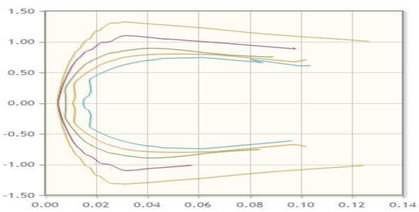

Figure 13: Cl Vs C_d

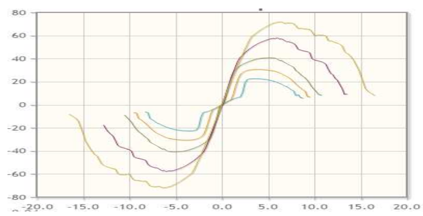

Figure 14: C_l/C_d Vs Alpha

Wing Design and Fuselage Design

For a wing set to provide long endurance, it should be optimized for the cruise flight, henceforth the wing loading (WL) should be selected, to provide maximum aerodynamic efficiency (CL/CD) at the cruise conditions. For a propeller aircraft, which loses thrust efficiency as speed goes up, gets the maximum endurance when flying at the speed for best CL/CD. The speed for best CL/CD can be shown to result in parasite drag, equaling the induced drag. Therefore, to maximize the endurance during cruise, a propeller aircraft should fly such that:

$WL = 1/2\rho V^2 * (\sqrt{\pi AReCD_0}) = 95.45\ Nm^{\wedge}{-2}$

The wing span, tip chord and the root chord are calculated using these relations:

$c_r = 2s/(1+\lambda) = 0.225\ m$; $c_t = \lambda * c_r = 0.113\ m$

The length of the fuselage is estimated using the equation is $F_L = b^{0.5} = 1.2\ m$

Table 4: Airfoil Selection, Wing Design Parameters and Fuselage Design

Airfoil Selection	Wing Design Parameters	Fuselage Design
Wing = Fx63-110	Fx 63-110(chord length) = 214.69,177'107.35	Fuselage length= 1200
Horizontal tail= S9026	Wing span = 1451.30	Diameter = 100
Vertical tail= S9027	Aspect ratio =5	Height =100
	Dihedral angle = 15	
	Wing area = 245000	

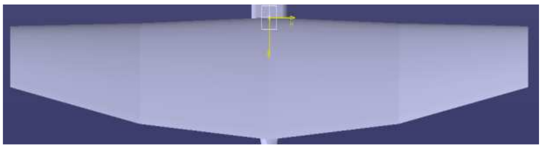

Figure 15: Wing

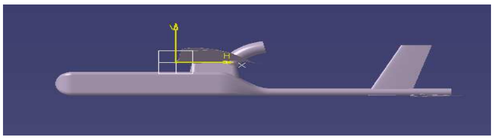

Figure 16: Fuselage

Empennage Design

The values of Vh and Vv are obtained from the literature. Typical aircraft values of 0.6 and 0.04 are chosen respectively.

$V_H = l_t s_H / cs \Longrightarrow s_H = 0.045\ m\text{^}2$

$V_V = l_t s_V / bs \Longrightarrow s_V = 0.026\ m\text{^}2$

Table 5: Horizontal Tail Design and Vertical Tail Design

Horizontal Tail Design	Vertical Tail Design
Chord length = 118,59	Chord length = 125.20, 87.90
Aspect ratio = 5	Aspect ratio = 2
Taper ratio = 0.5	Taper ratio = 0.7

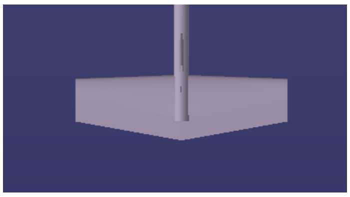

Figure 17: Horizontal Tail

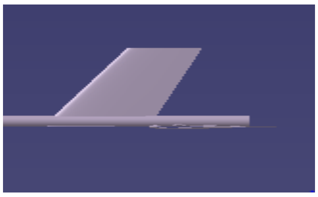

Figure 18: Vertical Tail

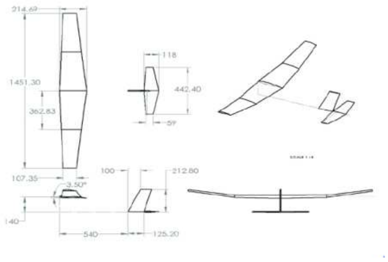

Figure 19: Wing and Tail Dimensions

ANALYSIS

Importing Geometry

The model is designed in CATIA and it is imported into fluent.

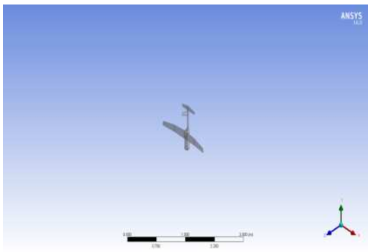

Figure 20: Geometry

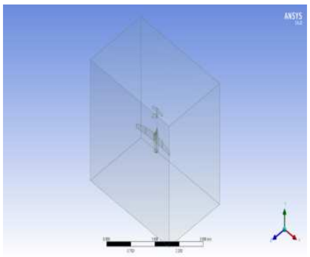

Figure 21: Domain

Mesh Generation

Mesh type is hexahedral unstructured grid

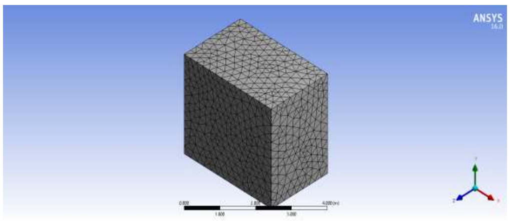

Figure 22: Mesh

- Inlet (the flow is towards the wing body)
- Outlet (the flow leaves the wing body).
- Wall (the other surface of the enclosed square are represented as wall)

The results for a given velocity has been observed for Mini UAV, a brief description has been given about the flow on the Mini UAV based on below input boundary conditions and The results shown here are Pressure, Velocity, Density contours and vectors at velocity of 31 m/s for Mini UAV, for input boundary conditions mentioned below.

Table 6: Input Boundary Conditions

Velocity of Flow	31m/s
AOA	0^0
Density of fluid	1.225 kg/m3

Table 6: Contd.,	
Operating Pressure	101235 pa
Turbulence model transaction	k-epsilon(2 equation)
Reynolds number	$2*10^5$
Fluid	Air as an Ideal
Operating Temperature	300 k
Kinematic Viscosity	1.4607*10^-5

Iterations

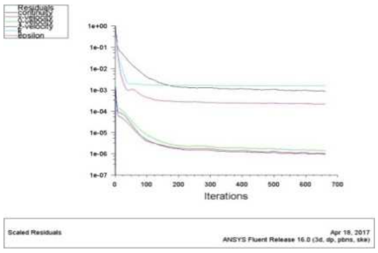

Figure 23: Scaled Residuals

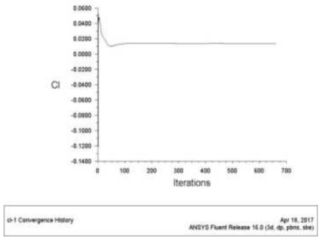

figure 24: C_l Vs Iterations

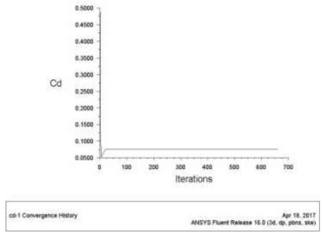

Figure 25: C_d Vs Iterations

RESULTS AND DISCUSSIONS

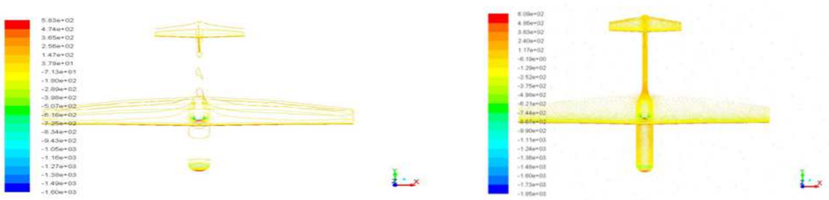

Figure 26: Static Pressure Contours and Vectors

From the above Figure the maximum Static pressure value is obtained at 1.85e+3 for pressure 101235 Pa at AOA 0^0

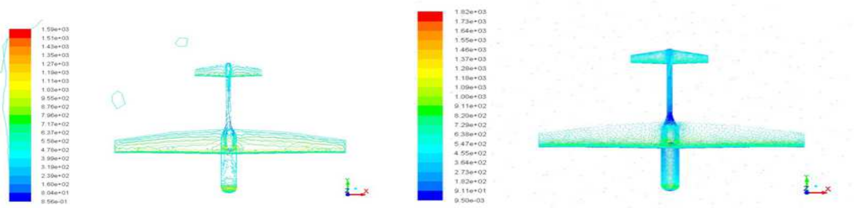

Figure 27: Dynamic Pressure Contours and Vectors

From the above figure the maximum Dynamic Pressure velocity is obtained at 9.05e+3 for pressure 101235Pa at AOA 0^0

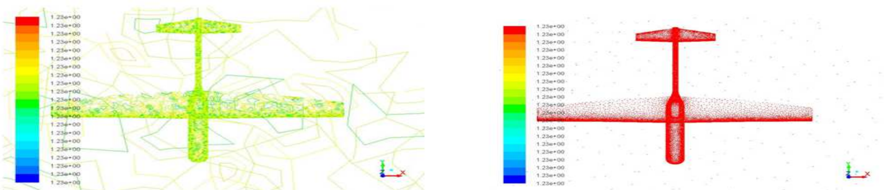

Figure 28: Density Contours and Vectors

From the above figure, the maximum density obtained at 1.23^e+3 and density considered as 1.23 at AOA 0^0

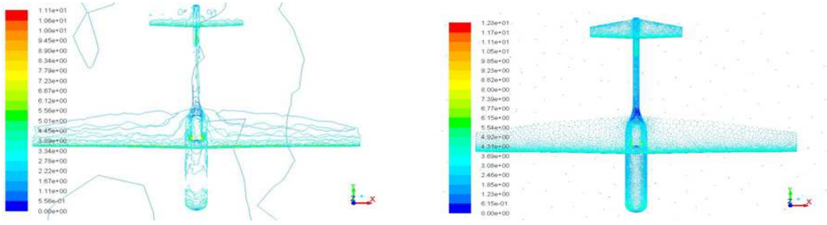

Figure 29: Wall Shear Stress Contours and Vectors

From the above Figures the maximum Shear stress is obtained at 1.23^{e}+01 for temperature 300k at AOA 0^{0}

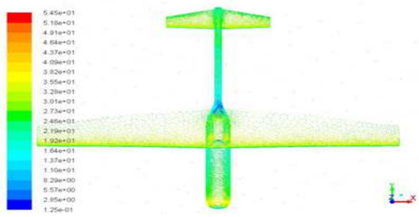

Figure 30: Velocity Vectors

From the above figure the maximum velocity obtained at 5.4^{e}+01 for 31m/s at AOA 0^{0}

CONCLUSIONS

- A mini UAV for surveillance mission was designed and developed using the implementation of a novel design methodology, with an AUW of max 2.5 kg and the maximum wing span of 1.5 m.
- Aerodynamic characterization of the vehicle was done in ANSYS Fluent software and the coefficients were compared using the values obtained from XFLR tool and experimental values.
- Reasonable agreement between the results was attained.

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